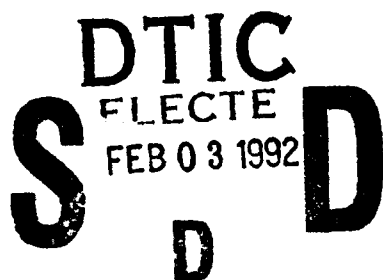# Marine Physical Laboratory

AD-A245 559

Continuation of the Interdisciplinary Research Program at MPL
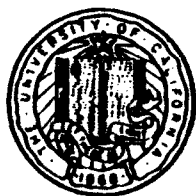
Kenneth M. Watson and Victor C. Anderson
Principal Investigator(s)

DTIC
ELECTE
FEB 0 3 1992
S D
D

*Final Report to the Office of Naval Research
Contract N00014-80-C-0220 for the
Period 1 January 1986 - 30 September 1990*

**MPL-U-68/90
September 1991**

Approved for public release; distribution unlimited.

University of California, San Diego
Scripps Institution of Oceanography

92-02511

92 1 31 033

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data need ed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. Agency Use Only (Leave Blank).	2. Report Date. September 1991	3. Report Type and Dates Covered. Final Report

4. Title and Subtitle.	5. Funding Numbers.
Continuation of the Interdisciplinary Research Program at MPL *Final Report to ONR Contract N00014-80-C-0220 for the Period 1 January 1986 - 30 September 1990*	N00014-80-C-0220

6. Author(s).

Kenneth M. Watson / Victor C. Anderson
(Principal Investigators

Project No.
Task No.

7. Performing Monitoring Agency Names(s) and Address(es).	8. Performing Organization Report Number.
University of California, San Diego Marine Physical Laboratory Scripps Institution of Oceanography San Diego, California 92152	MPL-U-68/90

9. Sponsoring/Monitoring Agency Name(s) and Address(es).	10. Sponsoring/Monitoring Agency Report Number.
Office of Naval Research Department of the Navy 800 North Quincy Street Arlington, VA 22217-5000	

11. Supplementary Notes.

12a. Distribution/Availability Statement.	12b. Distribution Code.
Approved for public release; distribution is unlimited.	

13. Abstract (Maximum 200 words).

The ARL:MPL Program collectively with the other univeresity ARL-Laboratories (APL:UW), ARL:UT, ARL:PSU) formed a research component with the Navy's technology base program that was especially well qualified in research and development in underwater science and technology. The ONR guideline for work conducted under the ARL:MPL Program contract was to involve MPL graduate students and faculty on research problems having naval relevance. The research areas addressed included: ocean environmental acoustics, marine physics and geophysics, ocean technology; acoustic technology; signal processing; and ocean instrumentation.

14. Subject Terms.			15. Number of Pages. 24
ocean acoustics signal processing marine physics and geophysics sonar imaging	seamount magnetism Doppler sonar Swallow floats vertical arrays	Deep Tow Sea Beam bathymetric system	16. Price Code.

17. Security Classification of Report. Unclassified	18. Security Classification of This Page. Unclassified	19. Security Classification of Abstract. Unclassified	20. Limitation of Abstract. None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

Table of Contents

Continuation of the Interdisciplinary Research Program at MPL

Kenneth M. Watson/Victor C. Anderson
(Principal Investigators)

1. Introduction

The subject contract was issued for the performance period 1 January 1986 thru 30 September 1990, in response to ARL:MPL proposal UCSD 1629, dated 19 December 1979[1]. Funding for the "ARL Program" came out of the ONR discretionary block support which also supported ARL block funding for ARL:UT, APL:UW, ARL:PSU. The ARL Program is administered by Dr. Marshall Orr and Mr. Marvin Blizzard, Code 11250A. The total cumulative amount of this contract was $3,475,196. The ARL contract was succeeded by ONR Grant N00014-90-J-1275, which was issued in response to ARL:SIO:UCSD proposal UCSD 89-1540, dated 19 July 1989[2] which includes the performance period 1 October 1989 through 30 September 1990.

Three detailed annual reports[3,4,5] were prepared and completed for ONR on the subject contract for fiscal years 1980-83, 1984, 1985. These were comprehensive in the research results and accomplishments on the research projects listed in Table 2.

The final report presented here will summarize contractual information and will offer a few project summaries and bibliographic data on the documented results and achievements.

2. Background

The ARL:MPL Program collectively with the other university ARL-Laboratories (APL:UW, ARL:UT, ARL:PSU) formed a research component with the Navy's technology base program that was especially well qualified in research and development in underwater science and technology. The ONR guideline for work conducted under the ARL:MPL Program contract was to involve MPL graduate students and faculty on research problems having naval relevance. The research areas addressed included: ocean environmental acoustics; marine physics and geophysics; ocean technology; acoustic technology; signal processing; and ocean instrumentation.

The ARL research program augmented a variety of research conducted at MPL in three ways:

1. It provided seed money for new research efforts at a modest level that capitalized on other experiments for which substantial assets have been deployed and/or substantial environmental data acquired;

2. It provided seed money for innovative new concepts, theoretical, or experimental, to be investigated and led, in some cases, to substantial research programs under other funding;

3. It provided a means by which new investigators were recruited and supported until they developed their own research support.

This support also resulted in the development of a broad range of scientific talent of which several new investigators have joined MPL on a permanent basis. They are active and productive in pursuit of the objectives of our Navy Mission Statement:

> To investigate and apply knowledge about the ocean, its boundaries and their surrounding media to the solution of the Navy's problems in anti-submarine and pro-submarine warfare;

> To provide research training of students in areas of oceanography and ocean technology which have application to Navy requirements;

> To maintain certain special ocean engineering, research and development capabilities which are essential to the Navy.

3. Contractual Information

The full period of performance of the ARL:MPL:SIO/UCSD program spanned a full ten year period from 1 January 1980 through 30 September 1990. A summary of the ARL program is given in Table 1. In addition, support was provided for eight high school

students who worked on summer projects under the ARL:MPL Defense Science and Engineering Apprenticeship Program [6,7]. A summary of listed projects is given in Table 2.

TABLE 1. ARL Program at MPL/SIO/UCSD

	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89
$K	250.0	275.0	300.0	370.0	400.0	400.0	358.86	319.43	331.18	400.0
No. Active Project	7	7	7	6	12	12	8	8	9	10
No. Faculty	5	5	5	6	7	7	8	11	11	12

TABLE 2. ARL:MPL Project Listing

	Project	Principal Investigator
FY80-FY82	Inverse Beamforming	Hodgkiss
	Swallow Float Low Frequency Noise Measurements	Anderson/ Hodgkiss
	Vertical Dependence	Williams
	Geomagnetic Background Study	Spiess
	Nonstationary and Nongaussian Statistics	Hodgkiss
	Deep Tow Thruster	Anderson
	High School Undergraduate Apprenticeship Program	Watson
FY83	Freely Drifting Swallow Floats	Anderson/ Hodgkiss
	Pressure Dependence of Sound Absorption	Fisher
	Spectral Fine Structure Characteristics	Hodgkiss
	Deep Tow Post Doctoral Investigation	Spiess
	Deep Sea Accumulator	Anderson

	Project	Principal Investigator
	Normal Mode Steering	Anderson
FY84	Acoustic Navigation	Anderson
	Under-Ice Reverberation	Hodgkiss
	Deep-Tow Post Doctoral	Spiess
	Non-Destructive Wire	Spiess
	Pressure Dependence and Sound Absorption	Fisher/ Dickson
	High Resolution Scattering	Pinkel
	Deep Sea Accumulator	Anderson
	Vertical Dependence	Fisher
	Deep Tow Thruster Pod	Anderson
	Spectral Fine Structure	Hodgkiss
	Visiting Scholar	Watson
	Lectures/Seminars	Watson
	Undergraduate Program	Hodgkiss
	High School Apprenticeship	Hodgkiss
FY85	Deep Sea Accumulator	Anderson
	High Resolution Forward Scattering Sensing	Pinkel
	Under-Ice Reverberation Cancellation	Hodgkiss
	Activity Coefficients in High Temperature Aqueous Solutions: A Hydration Model	Dickson
	Fine Scale Seafloor Magnetism	Hildebrand
	Determination of the Internal Electro-Acoustic Characteristics of an Underwater Resonant-Bubble Acoustic Transducer	Andrews
	High Resolution Spatial Spectral Estimation	Hodgkiss
	A Saltwater Hydraulic Thruster	Anderson
	High School Apprenticeship Program	Hodgkiss
	Undergraduate Student Support	Hodgkiss
	Visiting Scholar Support	Watson
	Visiting Lecturers/Seminars	Watson
FY86	Fine Scale Seafloor Magnetism	Hildebrand
	Cable Tethered Ocean Bottom Seismograph	Dorman/ Hildebrand
	Software Integration of Image Processing Systems	Lowenstein

	Project	Principal Investigator
	Doppler Acoustic Scattering from the Sea Surface	Pinkel
	Coherent Processing of Water Path and Sediment Borne Acoustic Energy	Hodgkiss
	Acoustic Research Appointment	Anderson/ Hodgkiss
	Acoustic Calibration Facility	Anderson
	Undergraduate Internship Program	Hodgkiss
	Lectures/Workshops and Seminars	Watson
FY87	Fiber-Optic Telemetered Ocean Bottom Seismography Array	Dorman/ Hildebrand
	Sea Beam as a Volumetric Tool: A Feasibility Study	Alexandrou/ De Moustier
	Sea Surface Current Measurements Using Doppler Sonar	Smith/Pinkel
	Investigation of Flow Noise Contamination for VLF Sensors	Anderson
	Pressure Fluctuations and Benthic Boundary Layer Turbulence	Webb
	Determination of the Potential Flow Characteristics of a New Foil for Underwater Applications	Andrews
	Coherent Processing of Water Path and Sediment-Borne Acoustic Energy	Hodgkiss
	ARL Workshops/Seminars/Visiting Scientists	Watson
FY88	Development of State-of-the-Art Electrochemical Instrumentation for the Analysis of Sea Water	Dickson
	Mini-Image Processing System	De Moustier/ Lowenstein
	Ultra-Low Frequency Seafloor Displacement Sensor	Hildebrand/ Dorman/ Webb
	Remote Surface Wave Elevation Sensor	Smith/Pinkel
	Sea Beam Navigation System	De Moustier
	Sidelobe Control and Null Steering for Large Aperture Arrays	Hodgkiss
	Investigation of Anthropormorphic Actuators and Linkages for Underwater Manipulator Applications	Anderson
	Workshops and Seminars	Watson
	Postdoctoral Appointments	Watson
FY 89	Seafloor Array for ULF Acoustic Studies	Webb/ Dorman
	Oblique Transmitting Transducer	Pinkel/Smith

Project	Principal Investigator
Investigation of Anthropormorphic Actuators and Linkages for Underwater Manipulator Applications	Anderson
Shallow Water Swath-Mapping System	Jaffe
Calibration Facility for Large Towed Sidescan Acoustic Array	De Moustier
Active Ballasting of Freely Drifting Sensors	Hodgkiss
Geological Dives with *Sea Cliff*	Lonsdale
The Effect of pressure on $MgSO_4$ Absorption in Sea Water at O^o and 1000 atm	Fisher
Workshops and Seminars	Watson
Postdoctoral Appointments	Watson

4. Research Results

The following are projects summaries of the scientific work produced under the subject contract. Also included in bibliographical format, are abstract summaries of the scientific documentation produced as the end product of the subject contract. We are including work begun under the preceding contract, but was either finished or reported during the subject contract is also listed.

4.1 Project Summaries

Presented here are a few project summaries with the funded project listed first, followed by the name of principal investigator. Some will be quite lengthy.

1. **Geomagnetic Background Study (F. N. Spiess)**

   The purpose of this project was to use our Deep Tow system to determine the fine scale nature of the earth's magnetic field in the vicinity of major topographic features with resolution sufficient to be relevant to evaluation of the geomagnetic background that would be the limiting external noise for postulated new airborne submarine magnetic detection devices.

   The approach was to make surveys using a near bottom towed magnetometer and, from the resulting data, to calculate, by upward continuation, the nature of the magnetic anomalies at aircraft search heights above the ocean. In this manner a proton precession magnetometer of conventional capability would produce a field description with detail comparable to that which would be relevant to the newest proposed sensors.

   The program was formulated to last for three years. The first year was to make surveys of two seamounts. The second year was to cover reduction and analysis of the first year's data and a survey of a major linear (scarp) feature, with the final year to complete data analysis and reporting.

   The first year's work was carried out in the form of a successful expedition, using *R/V NEW HORIZON*, to do a near-bottom deep tow survey of the upper portions of the Jasper Seamounts off the Southern California coast. The magnetic, topographic, and transponder navigation data were of good quality, as determined both at sea and in preliminary analyses ashore.

   For a combination of budgetary and programmatic reasons, a decision was made not to fund the program for the subsequent years. As a result, the planned data analyses and interpretations, budgeted for the second year, were never carried out.

2. **Multibeam Deep Towed Earth Mapping Sounder (F. N. Spiess)**

   This project began under the preceeding contract and was finished during this subject contract. The purpose of this task was to initiate design work to provide a multibeam swath mapping, echo sounder system having angular resolution characteristics comparable to the ship-mounted Sea Beam system, but to operate from a towed body at heights off-bottom ranging from 50 to 500 meters. The primary motivation is to provide comparable bottom topographic data sets at several different scales for use in testing hypotheses emerging from particular statistical descriptions (e.g. fractals) of seafloor roughness.

This was an on-going project. Within contract N00014-80-C-0220 a small amount of preliminary design work was done, confirming the feasibility of producing a system operating in the 100 kHz frequency range, with at least 16 beams having 2° - 3° beamwidths, all within the dimensional constraints of the current Deep Tow vehicles. In this phase it was also determined that, although the telemetry constraints are severe, it would be both preferable and feasible to send the (digitized) outputs of individual receiving elements up the wire and carry out the beamforming process in the towing ship rather than below in the towed vehicle. The principal reasons for doing this was, first, to allow flexibility in altering the beamformer to provide for additional beams in the future, and, second, to allow greater flexibility in use of echo amplitude and shape information for purposes other than simple echo sounding.

Based on this preliminary activity (and related funding commitment) ONR agreed to proceed with the construction of equipment and its use at sea over the following succeeding years. In this sense this project is a prime example of the usefulness of this contract in providing seed money for projects whose total cost goes beyond the funding capabilities of this contract.

3. **Improvements of the Effectiveness of Sea Operations with Cable Connected Vehicles (F. N. Spiess)**

This small project focused on the possibility of carrying out non-destructive examination of electromechanical cables of a particular type -- coaxial electrical cable core with two layers of helically laid, opposite wound steel strands. This type of wire is frequently used in oceanographic work, particularly for operation of deeply towed instrument packages. The primary problem that is difficult to detect is degradation of strength due to broken strands in the inner lay.

Our first step was to look into various non-destructive testing approaches. Acoustical methods proved impractical for use while the wire was in motion and a stop-start wire winding operation would be too time consuming. Eventually we found a commercial unit well matched to the problem. It essentially determines (on a relative basis) the magnetic flux linkage from a magnet along a short section of wire ~5 cm). When a section with a broken strand passes through the instrument the sudden change of flux is picked up as an electrical signal and displayed on a strip chart recorder and as an audible signal in a loudspeaker.

One unit was purchased, having pickup size matched to our 0.68" diameter cable. The unit quite effectively detected signal strand discontinuities in the inner lay of this wire. The system was tested in two environments. One was during an experiment done by our group to investigate the durability of splices in wire of this type. The geometry of an optimum splice was such that for a length of about 50 m there was one strand discontinuity per meter. As this splice was cycled back and forth under tension the detector was wrapped around it and it unerringly recorded each strand gap. The other occurred at sea near the end of a Deep Tow operation as we wound in the wire on board ship. In this instance no discontinuities were detected, other than one in a short test section of wire used while adjusting gain settings on the inspection system.

While these tests indicated that this type of wire could be monitored with this system, they also brought us face to face with a number of realities. First is the fact that this type of wire occasionally has lumps of debris adhering to it, particularly extruded lubricant material. Since the detector must fit snugly around the wire it must be installed in such a manner as to break free if a jam occurs, and be watched carefully while winding wire. Second, there have been very few mechanical failures in recent time, because of improved design and NSF purchases of new wires. Thus, the minor inconveniences of mounting and monitoring a new device have

outweighed the need for inspection beyond electrical measurements and external visual inspection. As budgets tighten, however, we will work with the others primarily responsible for such wire (principally WHOI, LDGO and U. Wash) to move this technique into accepted use and thus reap the benefit of this modest investigation.

4. **Deep Tow Post-Doctoral Investigation (F. N. Spiess)**

The MPL post-doctoral researchers program is designed to bring new investigators into the field of marine physics (as epitomized by the MPL research program). One billet in this program was granted to the Deep Tow under the direction of Dr. F. N. Spiess. On the basis of appropriate advertising and inquiries throughout the underwater acoustics/signal processing/geophysics fields, Dr. John Hildebrand was recruited into this position. Dr. Hildebrand did his undergraduate work at UCSD. He then went to Stanford University, where he carried out a doctoral program in applied physics. His thesis involved use of ultra-high frequency acoustics to image biological samples in an enlarged (microscope) fashion. At Stanford he also was involved in geophysics courses.

Upon arrival at MPL he immediately was involved with our program of research and instrument development in relation to the fine scale properties of the deep sea floor. This experience emphasized the development of seagoing experimental skills and work on analysis and interpretation of the types of data (side looking sonar, magnetometer, cameras, transponder navigation, etc) collected with the Deep Tow system.

Hildebrand very quickly moved into the mode of independent generation of new research ideas and instrumentation concepts. As the period of this postdoctoral support drew to a close he was offered (and accepted) a permanent research position in the Marine Physical Laboratory, followed by appointment as an Assistant Professor. This, as we had hoped, was a very fortunate and effective result of our post-doctoral program investment.

5. **Remote Surface Wave Elevation Sensor (J. A. Smith/R. Pinkel)**

Over the past few years, we have been developing a Doppler acoustic system for measuring surface waves and currents. To assist in this endeavor, we have also deployed resistance wave wires as a backup/verification for the sonar measurement of the waves, and also to extend the measurements to higher frequencies. One problem with the wires then in use was the tendency to break in heavy weather. The purpose of this project was to assess the feasibility of using alternate techniques such as microwave, laser, or acoustic ranging (from above the water).

The first task was to evaluate which of the available systems was the most likely to be cost-effective while achieving our resolution goals (about 1 cm accuracy with 10 Hz sample rate or better). Acoustic ranging degrades with wind noise at higher wind speeds, and so promised no better weather "tolerance" than the wire system. The laser-based measurements appear promising, but light detectors with sufficient dynamic range to ensure detection of the reflected signal (yet not suffer overload on the specular hits) are prohibitively expensive. Finally, we decided to try a microwave Doppler system developed by TSK, which is designed for heavy weather use from the bow of a ship, and retails for about $20k. The unit has built-in motion compensation, and automatically evaluates dominant wave height and period (in addition to providing a recordable serial and analog outputs). One of the TSK microwave units was kindly provided on loan from the company for our at-sea test, which took place in November 1987.

The tests we ran consisted of side-by-side comparisons with the existing resistance-wire system. These tests were run from two locations aboard FLIP: one from the port boom, about 15m above the mean surface, and the other from the engine room deck, at about 5.5m. The former location has the advantage of being several diameters away from the hull of FLIP, while the latter has the advantage of being quite stable, minimizing the effects of FLIP tilting and rotating.

The comparison is most clear in terms of the spectral coherence (see Figures 1 and 2). With a 26° beamwidth for the microwave system, the spot sizes were about 6.7m from the boom and 2.5m from the engine room deck. Assuming one full wavelength as the cutoff, these correspond to frequencies of about 0.48 Hz and 0.79 Hz, respectively. At both locations, the spectral coherence between the two systems falls off at a frequency corresponding nicely to the spot size of the microwave system
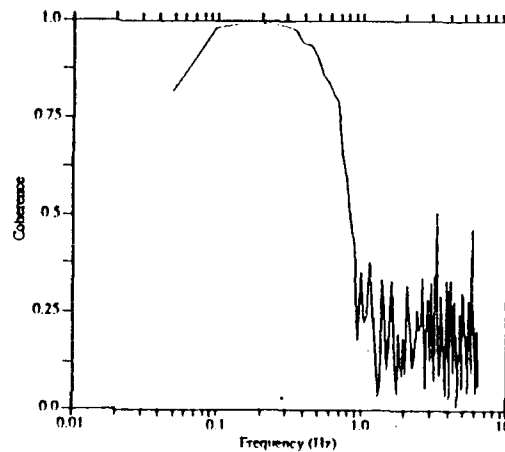

Figure 1. Coherence between resistance wire and TSK microwave systems, from data taken 5.5 m above the mean surface (FLIP engine room deck). The TSK spot size is about 2.5 m, corresponding to a wave frequency of about 0.8 Hz.
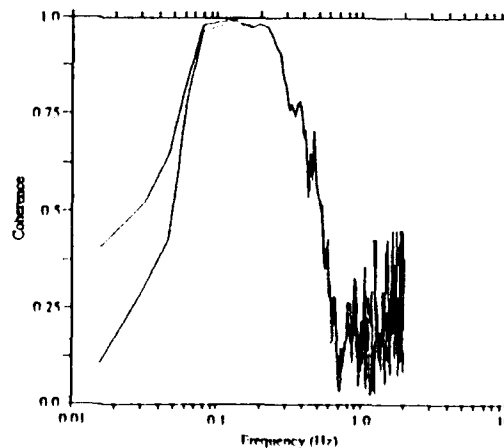

Figure 2. Coherence vs frequency between the TSK microwave unit and a resistance wire, from a location 15 m above mean sea level (a boom on FLIP). The TSK spot size in this case if 6.7 m, corresponding to a frequency of about 0.5 Hz. The (initially) higher coherence is between the "raw" TSK output and the wire, while the lower values result from using the motion compensated TSK output. As inferred, FLIP's motion is predominately low frequency. Motion compensation is available also for the wire data.

In general, the TSK system performed admirably, giving robust results in a variety of conditions. In contrast, our wire systems suffered from electrical pickup from the sonar transmissions. However, as can be seen from the above analysis, the beam width of the microwave unit is quite broad, resulting in a spatial resolution no better than that of the sonars. Unfortunately, no commercial system seems to be available with any narrower beam pattern.

In view of this, we decided to spend the remainder of the funding on improving the wire system. These are by far the most economical of the systems considered, and appear to give the best chance for small-scale high-frequency results. A larger diameter resistance wire is now used, which greatly improves the reliability in high winds (none of the new wires has broken in use yet). Also, the electronics were modified, both to accommodate the smaller resistance of the thicker wire, and to provide additional filtering to remove the electrical "pick up" from sonar transmissions. The new wire system was successfully deployed as part of SWAPP (which also helped fund the revisions), and performed well throughout. In addition, a manual was produced on how to deploy and use the new wire system, in anticipation of participation in the (cancelled) FLOSS experiment. The system was also successfully deployed by people having no previous experience with it, as part of the NOSC Optical Propagation Experiment.

6. **Shallow Water Swath-Mapping System (Jules S. Jaffe)**

The purpose of this multi-year investigation was to examine the theoretical and practical performance of a set of orthogonal frequency hop codes for sonar imaging. The majority of work performed under this contract was of an experimental nature which consisted of insonifying various test targets and measuring the performance of a set of frequency hop codes. This included both coherent and incoherent processing schemes.

The simultaneous transmission of a number of coded waveforms can provide a substantial advantage for sonar systems that rely on active techniques for imaging. In one example, the transmission of these different waveforms in separate directions can provide increased performance in sonar imaging applications where scan rate, resolution, and side-lobe suppression is desirable. We have referred to the idea of insonifying different parts of the medium with different sounds as spatially variant insonification [SVI].

Systems that use the principle of spatially variant insonification can have superior performance characteristics over conventional systems. Typical active sonar systems rely either on pulsing and scanning a small pencil shaped beam, or on insonifying the medium with an omnidirectional pulse and beamforming on the receive. The first type of system has good side-lobe rejection and low imaging rate. The second type of system can have a high frame rate but limited side-lobe rejection. It has been demonstrated that by using SVI higher frame rates can be achieved with superior side-lobe rejection over traditional systems. [Jaffe and Cassearau; 1988, Jaffe et. al; 1990][8,9].

The basic experimental setup consisted of a set of 16 arbitrary waveform synthesizers, each with it's own transmitting transducer and power amp. A set of frequency hop codes were loaded into each channel with a set of signals that satisfied the time-bandwidth constraints of the medium. The center frequency of the system was 900 kHz with a bandwidth of approximately 400 kHz.

The experiments that were performed consisted of insonifying a set of test targets (single targets) in the field of view of the sonar system and digitizing the response from a hydrophone that was listening to the reflection. The targets consisted of

materials that were meant to mimic both hard surfaces and distributed surfaces. In the case of the hard target, a copper sphere was used. In order to simulate a distributed set of scatterers a styrofoam ball was used.

The recorded waveforms were processed using two different methodologies. In the case of the coherent waveform processing, a simple cross-correlation was performed between the received waveform and a stored replica. The replica was recorded in the far field of the array. As such, any phase distortions that were present in the transmit and receive electronics were taken into account. In the case of incoherent processing the waveform was passed through a set of narrow band filters whose bandwidth was tuned to equal that of the individual frequency chips. Subsequent processing consisted of envelope detection and delay and sum addition.

The resultant waveforms were viewed and compared in order to distinguish between both the absolute and relative peaks versus side lobes. In the case of the reflections from both the hard and distributed targets the coherent processing scheme did not seem to perform better than the incoherent processing scheme. That is to say, the incoherent processing was necessary in both cases. Values of peak to side lobe for incoherent rejection were approximately 6 dB. This is an "in progress" number and it is hoped that more rejection between orthogonal signals can be obtained.

Additional interferences between the codes were manifest because of several types of effects. For one, since the signal spanned almost an octave, the beam patterns for the different frequencies were very different. Additionally, the different propagation efficiency of the transmitters was different for different signals. Our plans are to compensate for this effect using our arbitrary waveform synthesizer. This will allow equalization for the different frequencies. Although the different beam patterns cannot be compensated using our current system future techniques could take advantage of this effect.

Our initial results using Spatially Invariant Insonification in our test tank system have illustrated several problems which were not envisioned in the system design stage, but which can be addressed using a combination of both digital synthesis and processing techniques. In addition, lack of temporal coherence in our experimental system seems to limit our codes to incoherent processing techniques. We are currently exploring ways to incoherently process the data that takes into account the time varying nature of the medium while, at the same time, takes into consideration the wide band nature of our system. In this way, the many advantages associated with wide band imaging can be utilized.

7. **ARL:MPL Postdoctoral Appointments (K. M. Watson)**

Adding new and, in particular, younger members to the Marine Physical Laboratory staff was essential in sustaining the long-term quality of the Laboratory's Navy research program. The funding under the current ARL contract provided the principal funding mechanism for doing this. By sharing the costs with other MPL contracts, the ARL funds provide a very significant lever.

At the outset of the ARL program the MPL scientific staff was heavily weighted with scientists who were within 10 to 15 years of retirement. A vigorous recruitment program was begun to recruit young scientists for the MPL staff. The ARL Program provided the critical funds for doing this.

The following scientists have been brought to the Marine Physical Laboratory using initial support from the ARL Program.

Dr. John Hildebrand. (Professor at MPL, hired 8/18/83 to present) His work has been in acoustics and marine geophysics. He developed the MPL 1 and 3 km acoustic arrays and helped develop the Navy OBS system.

Dr. Spahr Webb. (Assistant Research Oceanographer at MPL, hired 9/15/86 to present). His work is in low frequency acoustics and is now supported by Navy 6.1 and 6.2 funds.

Dr. Angela Barone. (MPL Postgraduate Staff, hired 1/1/90-to present). Her work is in marine geology and morphology.

Dr. Mike Buckingham. (Professor at MPL and SIO, hired 1/1/90 to present). His theoretical and observational work is in marine acoustics.

Dr. Jeff Krolik. (MPL Research Staff, hired 9/1/90-to present). His work is in marine acoustics and signal processing which augments the program of Dr. W. S. Hodgkiss.

The ARL Program is providing MPL with an effective mechanism to expand its research staff and to replace retirees.

4.2 Archival Publications

Following is a listing of bibliographical data as well as the abstract of each paper that appeared in referrd journals. Also included are publications that have been submitted, but are still in the editing process.

1. Fisher, F. H. (1988), "FLIP II," IEEE Journal of Oceanic Engineering, Vol. 13, No. 4, pp. 174-185.

After 26 years of operations at sea with the Research Platform FLIP, a 355-ft-long craft which has a draft of 300 ft in the vertical position, planning is underway for a larger, more capable FLIP II that can operate in seas with waves of up to 80 ft and survive more severe seas. As our research in acoustics extends to studies of ambient noise and propagation at lower frequencies, recent deployments of large aperture (900 m), multi-element (120) arrays tax the space and facilities on FLIP. Future plans include deployment of 240 element, 3500 m arrays as well as large, powerful sound sources that further tax the limits of current capabilities.

The original FLIP, while designed to work in 30-ft waves with no more than a 18 percent heave response, has survived 80-ft swells (22 s period) with only minor damage. Research requirements for greater laboratory and deployment capabilities to make possible joint multi-disciplinary/group operations and the need to work in regions with worse weather cannot be met with the current FLIP nor is it economically or structurally feasible to modify it to do so. Along with a brief description of FLIP, this paper lists the variety of research conducted from FLIP in both the Pacific and Atlantic Oceans and whether it was in drifting or moored deployments in deep water. While originally built for acoustic research, it has also been used for physical oceanography, meteorological, and biological studies. A recent workshop on research platforms highlighted the needs of several different scientific communities for a larger, more capable FLIP-type vessel with a minimal air and water column profile that can work in severe weather.

The purpose of this paper is to invite the interest and attention of the scientific and engineering communities regarding the design and potential uses of a larger FLIP II. Current thinking centers around 420-ft-long, 30-ft-diameter hull with a smaller water plane diameter of 20 ft. All weather deployment capability of submersibles from the bottom of FLIP II (draft 340 ft) is considered. Preliminary design efforts have been initiated with a naval architect.

2. Crawford, W. C., S. C. Webb, and J. A. Hildebrand (1991), "Seafloor Compliance Observed by Long-Period Pressure and Displacement Measurements," Journal of Geophysical Research, Vol. 96, No. B10, pp. 16,151-16,160.

Ocean surface waves with periods longer than 30 s create periodic, horizontally propagating pressure fields at the deep seafloor. Seafloor displacements resulting from these pressure fields depend on the density and elastic parameters of the oceanic crust. The displacement to pressure transfer function, the seafloor compliance, provides information about ocean crustal density and elasticity, and we outline a linearized inversion method to determine ocean crustal shear velocity from the compliance. By computing compliance partial differences with respect to changes in ocean crust shear velocity, we provide estimates of inversion stability and of the compliance sensitivity to crustal properties. Seafloor compliance, measured from pressure and acceleration spectra, is presented for two different sites: Axial Seamount on the Juan de Fuca Ridge and the West Cortez Basin in the California continental borderlands. The compliances and inverted structure for these two sites show significant differences; in particular, a zone of low shear strength is observed at depth within Axial Seamount, suggesting the presence of at least 3% partial melt within the upper 2500 meters of the ediface. These results suggest that the method provides a useful new geophysical prospecting tool.

3. Hildebrand, J. A., and R. L. Parker (1987). "Paleomagnetism of Cretaceous Pacific Seamounts Revisited," Journal of Geophysical Research, Vol. 92, No. B12, pp. 12,695-12,712.

The paleomagnetism of Cretaceous Pacific seamounts is reexamined. Herein techniques for nonuniform magnetic modeling are applied to determine paleomagnetic pole positions and their associated confidence limits. Modeling techniques are presented for reconstruction of both uniform and nonuniform components of the seamount magnetization. The uniform component yields an estimate of the paleomagnetic pole position, and the nonuniform component accounts for irregularities in the seamount magnetization. A seminorm minimization approach constructs maximally uniform magnetizations and is used to represent seamount interiors. A statistical modeling approach constructs random nonuniform

magnetizations and is used to determine the confidence limits associated with each pole position. Mean paleopoles are calculated for groups of seamounts, including their associated error bounds. The mean paleopole for seven reliably dated Upper Cretaceous seamounts is located close to the position prediced by Pacific-hotspot relative motion. The paleopole for five seamounts with Cretaceous minimum dates is located west of the hotspot-prediced apparent polar wander path and may represent a Lower Cretaceous or Upper Jurassic pole.

4. Hildebrand, J. A. (1989), "The Paleomagnetism of Eastern Nazca Plate Seamounts," Tectonophysics, Vol. 70, pp. 279-287.

Paleomagnetism of eastern Nazca plate seamounts defines Nazca and Farallon absolute plate motion during Cenozoic times. Magnetic and bathymetric surveys are presented for two eastern Nazca plate seamounts in the Chile Basin and they are used to calculate paleomagnetic poles with uniform and nonuniform magnetic modeling. The paleopole for Piquero-2 seamounts is coincident with the earth's pole, suggesting a young seamount. The paleopole for Piquero-1 seamount indicates that the Nazca plate moved 23° more motion than predicted by DSDP sediment and basalt paleomagnetism.

5. Hildebrand, J. A., and H. Staudigel (1986). "Seamount Magnetic Polarity and Cretaceous Volcanism of the Pacific Basin," Geology, Vol. 14, pp. 456-458.

In this paper we examine the magnetic polarity for Pacific Basin seamounts exclusive of the Hawaiian Ridge. On Pacific crust older than 65 Ma, seamounts of normal polarity predominate. On crust younger than 65 Ma, seamounts exhibit normal and reversed polarity as well as mixed polarity. We show that viscous components do not dominate seamount magnetization, and we suggest that a large number of normal seamounts were formed during a major magmatic event postulated for the period 110-70 Ma. This period overlaps with the long Cretaceous normal period (188-84 Ma) and corresponds to 85% normal polarity for Earth's magnetic field. The correspondence of a period of high magmatic activity with a long period of normal polarity supports the possible correlation between those processes responsible for magma production and for magnetic field generation.

6. Hildebrand, J. A. (1990). "Technologies for Geophysical Exploration on the Ocean Bottom," Appears In: Gorda Ridge - A Seafloor Spreading Center in the United States Exclusive Economic Zone (Edited by Gregory R. McMurray), Chapt. 12, 181-189 (Springer-Verlag, New York, Inc.).

Several approaches have been used for ocean bottom geophysical exploration including magnetic, gravity, and seismic methods. Magnetic anomalies near the ocean bottom are measured with a nuclear precession magnetometer deployed from a deeply towed vehicle. They reveal fine-scale crustal magnetization indicating geomagnetic field reversals and zones of varying lithology. Gravity anomalies of the ocean bottom are measured with a gravimeter placed on the seafloor. The seafloor gravimeter is more precise than sea surface gravimeters owing to greater platform stability, and it has improved capability for revealing crustal density structures because of its closer proximity to crustal sources. Ocean bottom seismic methods use on-bottom seismographs or hydrophones and on-bottom shots. Use of on-bottom seismic instrumentation allows characterization of shallow inhomogeneous crustal structure. Accurate positioning is needed for fine-scale ocean bottom geophysical exploration and may be accomplished with acoustic transponders and satellite navigation.

7. Hildebrand, J. A. (1986), "Thermoacoustic Generation in Anisotropic Media," Journal of the Acoustical Society of America, Vol. 79(5), pp. 1457-1460.

The generation of acoustic waves by a modulated thermal source is examined for anisotropic materials. A wave equation is developed to include the effect of a thermoacoustic source for the anisotropic case. The dependence of the thermoacoustic source term upon the material elastic constants is identified for a thermal source varying in one dimension. This dependence is examined for several classes of crystalline anisotropy and it is found that thermoacoustic generation varied with crystallographic orientation. The directions of maximum and minimum thermoacoustic generation are not consistent for a given crystal class and are dependent upon the specific values of the elastic constants for the material.

8. Hodgkiss, W. S. (1983). "The Effects of Array Shape Perturbation on Beamforming and Passive Ranging," IEEE Journal of Oceanic Engineering, Vol. OE-8, No. 3, pp. 120-130.

The problem of beam formation from a towed line array whose shape has been distorted is considered. Emphasis is placed on the broadening and range estimation effects of array shape perturbation and how the resulting losses can be regained if the actual element positions are known. Specific illustrations are provided for various levels of shape distortion. For example, a 15-m bow in a 232.5-m-long array broadens the beamwidth by a factor of 3 at 50 Hz. As another example, a 6-m bow in a 800-m-long array leads to a 20-percent range underestimation at 10 km for a 100-500-Hz broadband source.

9. Hodgkiss, W. S., and D. Alexandrou (1985). "Under-Ice Reverberation Rejection," IEEE Journal of Oceanic Engineering, Vol. OE-10, No. 3, pp. 285-289.

An adaptive joint process structure is described which rejects under-ice reverberation by taking advantage of the spatial separation between acoustic backscatter returning from small elevation angles and transmitted energy reflected off the sea surface.

10. Parker, R. L., L. Shure, and J. A. Hildebrand (1987). "The Application of Inverse Theory to Seamount Magnetism," Geophysics, Vol. 25, No. 1, pp. 17-40.

The traditional least squares method for modeling seamount magnetism is often unsatisfactory because the models fail to reproduce the observations accurately. We describe an alternative approach permitting a more complex internal structure, guaranteed to generate an external field in close agreement with the observed anomaly. Potential field inverse problems like this one are fundamentally incapable of a unique solution, and some criterion is mandatory for picking a plausible representative from the infinite-dimensional space of models all satisfying the data. Most of the candidates are unacceptable geologically because they contain huge magnetic intensities or rapid variations of magnetization on fine scales. To avoid such undesirable attributes, we construct the simplest type of model: the one closest to a uniform solution as measured by the norm in a specially chosen Hilbert space of magnetization functions found by a procedure called seminorm minimization. Because our solution is the most nearly uniform one we can say with certainty that any other magnetization satisfying the data must be at least as complex as ours. The theory accounts for the complicated shape of seamounts, representing the body by a covering of triangular facets. We show that the special choice of Hilbert space allows the necessary volume integrals to be reduced to surface integrals over the seamount surface, and we present numerical techniques for their evaluation. Exact agreement with the magnetic data cannot be expected because of the error of approximating the shape and because the measured fields contain noise of crustal, ionospheric, and magnetospheric origin. We examine the potential size of the various error terms and find that those caused by approximation of the shape are generally much smaller than the rest. The mean magnetization is a vector that can in principle be discovered from exact knowledge of the external field of the seamount; this vector is of primary importance for paleomagnetic work. We study the question of how large the uncertainty in the mean vector may be, based on actual noise, as opposed to exact, data; the uncertainty can he limited only by further assumptions about the internal magnetization. We choose to bound the rms intensity. In an application to a young seamount in the Louisville Ridge chain we find that remarkably little nonuniformity is required to obtain excellent agreement with the observed anomaly while the uniform magnetization gives a poor fit. The paleopole position of ordinary least squares solution lies over 30° away from the geographic north, but the pole derived from our seminorm minimizing model is very near the north pole as it should be. A calculation of the sensitivity of the mean magnetization vector to the location of the magnetic observations shows that the data on the perimeter of the survey were given the greatest weight and suggests that enlargement of the survey area might further improve the reliability of the results.

11. Pinkel. R. (1984). "Doppler Sonar Observations of Internal Waves: The Wavenumber-Frequency Spectrum," Journal of Physical Oceanography, Vol. 14, No. 8, pp. 1249-1270.

In May 1980 an 18-day sequence of velocity profiles of the top 600 m of the sea was collected off the coast of Southern California. The measurements were obtained using a pair of Doppler sonars mounted on the Research Platform FLIP. From these data, estimates of the wavenumber-frequency spectrum of the oceanic internal wavefield are obtained. The spectra are characterized by a series of ridges, which occur at near-inertial and tidal frequencies as well as higher harmonics and sums of these fundamentals. The ridges run parallel to the wavenumber axis. There is a pronounced near-inertial spectral peak. The near-

inertial motions are dominated by a few identifiable wave groups. There is a net downward energy propagation in the near-inertial frequency band. The vertical-wavenumber dependence of the spectrum is decidedly asymmetric in this region. The asymmetry extends to five times the inertial frequency, making much of the so-called continuum asymmetric. A high-wavenumber cutoff at approximately 60 m vertical wavelength extends from the inertial frequency to approximately 5 cycles per day (cpd). The changing form of the wavenumber dependence of the spectrum with frequency frustrates any simple attempt to assign a scale wavenumber bandwidth to the spectrum. The total variance of the downward propagating motions exceeds that of the upward, primarily because of an excess of downward near-inertial energy.

Surprisingly, the net energy transport of the wavefield is upward, of the order 0.003 W m^{-2}. The upward flux results from an excess of (5-60 cpd) upward propagating waves. Although these have much less variance than the downward propagating near-inertial waves, they have a far greater vertical group velocity.

12. Pinkel, R. (1985). "A Wavenumber-Frequency Spectrum of Upper Ocean Shear," Journal of Physical Oceanography, Vol. 15, No. 11, pp. 1453-1469.

In May 1980 an 18-day sequence of oceanic velocity profiles was obtained off the coast of Southern California. The measurements were made using a pair of Doppler sonars mounted on the research platform FLIP and angled downward 45°. The profiles extend to a depth of 600 m. Depth resolution is approximately 30 m. From these profiles the vertical wavenumber-frequency spectrum of the oceanic shear field, $\Phi(\kappa, \omega) \equiv (\partial u / \partial z)^2 / d\kappa d\omega$ is estimated.

The shear spectrum is resolved between vertical wavenumbers 1/530 and 1/28 cpm. It is band-limited in wavenumber in the frequency region encompassing near-inertial waves and semidiurnal tides. Motions of vertical wavelength between 100 and 300 m have the greatest shear spectral density. As frequency increases, the band of most energetic motions shifts to ever higher wavenumbers. At frequencies above 8 cpd only the low-wavenumber side of the energetic band can be resolved by the sonars. The wavenumber dependence here appears blue.

It is unlikely that the high-frequency, high-wavenumber shear is a result of linear internal wave activity. The spectrum $\Phi(\kappa, \omega)$ is not consistent with previous estimates of the spectrum of isotherm vertical displacement if linear internal wave scaling is used. The vertical displacement spectrum becomes progressively more red (low-mode dominated) with increasing frequency while the shear spectrum becomes progressively more blue. In ignorance of the dynamics of these motions, it is unwise to use internal wave (WKB) scaling to describe the vertical variation of the shear field.

13. Smith, J. (1987). "On Surface Waves Crossing a Step with Horizontal Shear," J. Fluid Mechanics, Vol. 175, pp. 395-412.

When surface waves encounter a step in bottom topography and/or a change in velocity parallel to the step, refraction and partial reflection occur. Comparison of several approximate solutions indicates that no single approximation works well for all cases. The pattern of success among models suggests that the velocity profile at the boundary favors the free wave with smaller vertical scale. For current changes over a flat bottom, a two-term Galerkin expansion (ef. Evans 1975) is employed for comparison with the other more general models. For small currents ($|\Delta v| < \frac{1}{2}c$), an 'action-based approximation' (cf. Smith 1983) is favored, although all models perform adequately. With a strong current, one-term (one-sided) model performs best, another worst among models; the favored model includes ephemeral modes on the side with larger-scale free waves. For changes in depth only, the one-sided model with ephemeral modes on the deep side was shown by Miles (1967) to perform well. The two-term expansion (cf. Evans 1975) is not easily extended to this case, and none of the other approximations perform adequately. In the unusual case of a step combined with a strong current, such that much shorter waves occur in the deeper region, it is inferred that none of the models are accurate. Reflection from a submerged wall provides a severe test of the models. Without the ephemeral modes, no net reflection occurs. The Miles-like model overpredicts reflection slightly.

4.3 Non-Archival Publications

Presented here are bibliographical data and abstracts for papers that appeared in non-refereed papers such as proceedings of symposia, conferences, and workshops.

1. Aleaxandrou, D. (1985), "Sea Beam Sidelobe Interference Cancellation," OCEANS '85 Conference, 12-14 November 1985, San Diego, CA. Vol. 1, pp. 473-476.

   The Sea Beam multibeam bathymetric system is in operation aboard research vessels worldwide. While it has contributed greatly in advancing the understanding of the deep-sea floor, several types of bathymetric artifacts have been identified in its contoured output which could be mistaken for sea floor structure. Among those, the "tunnel" effect results from sidelobe interference caused by the near specular return and is most prominent when the sea floor is relatively flat. It is characterized by a trough in the bottom profile produced by Sea Beam. It will be shown that this type of interference can be greatly reduced or eliminated through an adaptive filtering scheme, pending a minor modification of the Sea Beam data acquisition system. The noise-cancelling configuration of the adaptive least-squares lattice filter will be used to process simulated Sea Beam data obtained through REVGEN, a high-fidelity sonar system simulation program.

2. Anderson, V. C., and R. C. Horn (1984). "Remote Underwater Manipulator (RUM)," Proceedings of the Society of Automotive Engineers, West Coast International Meetings and Exposition, San Diego, CA, 6-9 August 1984, Paper No. #841012.

   This paper describes RUM III, a new remotely operated seafloor search and work vehicle being designed for use in the abyssal plains and spreading centers of the world's ocean basins. The vehicle will operate at the end of 10,000 meters of coaxial strain cable to a depth of 5000 meters. Anticipated uses include documented coring in the deep-sea floor, benthic ecology studies, investigation of spreading centers and deep-sea vents, development of assessment technology for polymetallic sulfide deposits, emplacement and replenishment of long term deep-sea instrument systems, and the recovery of lost instruments from the seafloor.

3. Currier, R. E. (1985). "RUM III Vehicle Control System," Proceedings of the OCEANS '85 Conference, 12-14 November 1985, San Diego, CA, Vol. 2, pp. 1045-1051.

   The hardware and software design of a control system for the RUM III vehicle project is described. The functional requirements, design constraints, and system configuration are first examined. A description of the hardware systems and their corresponding software components follows

4. Hildebrand, J. A., and W. S. Hodgkiss (1990), "Large-Aperture Arrays for VLF Ambient Noise and Signal Propagation Studies," Proceedings of OCEANS '90, Vol. CH2858, pp. 24-28.

   Substantial interest has been shown in the very low frequency (VLF) band in recent years. Arrays at these frequencies must have large-apertures to accommodate long acoustic wavelengths. Special attention must be paid to mechanical strum which can be a significant contaminant in this band. Also, large non-rigid array structures change position with time and their elements must be navigated to account for these motions. In this paper, design issues related to VLF arrays developed at the Marine Physical Laboratory will be discussed. Designed to be deployed from the R/V FLIP, one of these arrays has 120 elements equally spaced across a 900 m aperture. It is modular in construction and digitizes the data in the array modules themselves. Currently under development is a 64-element vertical array of DIFAR sensors which will provide azimuthal as well as vertical directionality. To avoid contamination from flow and strum noise, an array of 12 autonomous freely drifting Swallow floats has been developed. Recently, a bottom mounted array of 20 seismometers and hydrophones has been developed to study ULF/VLF acoustics at the water-seafloor interface.

5. Hodgkiss, W. S., V. C. Anderson, G. L. Edmonds, J. C. Nickles, and R. L. Culver (1986). "A Freely Drifting Infrasonic Sensor System," IEEE Proceedings of the Fourth Working Symposium on Oceanographic Systems, 4-6 February 1986, San Diego, CA, Vol. CH2269-9, pp. 79-84.

The design of an element of a freely drifting infrasonic sensor array is described. The intent of this measurement system is to gather wide aperture data sets which will be used both to characterize ambient noise in the region 1-10 Hz and to assess the gains possible from beamforming utilizing a collection of VLF (very low frequency sensors). Coherent processing (beamforming) of the infrasonic sensor data is made possible by relative position measurements derived from mutual acoustic interrogation of the elements at a high frequency.

6. Hodgkiss, W. S. and D. Almagor (1987). "An Eigenvalue/Eigenvector Interpretation of Surface Reverberation Rejection Performance," Proceedings of the International Conference on Acoustics, Speech and Signal Processing, Vol. CH2396-0, pp. 2027-2030.

The application of adaptive least-mean square (LMS) and least-squares lattice (LSL) algorithms to the rejection of sea surface reverberation is discussed. A specific dual channel noise cancelling structure is considered along with the results of processing a ping selected from an experimental ocean reverberation data set. A time-evolving eigenvalue/eigenvector decomposition is used to provide insight into the performance differences between the two adaptive algorithms in this highly dynamic physical geometry.

7. Hodgkiss, W. S., and R. K. Brienzo (1990). "Broadband Source Detection and Range/Depth Localization via Full-Wavefield (Matched Field) Processing," Proceedings of the International Conference on Acoustics, Speech and Signal Processing, Vol. CH2847-2, pp. 2743-2746.

The analysis here will illustrate the use of full wavefield (matched field) processing techniques in a multipath environment. Experimental data consists of the arrivals at a hydrophone array from an explosive source in shallow water. A coherent recombination of the multipath arrivals is performed in order to provide enhanced signal-to-noise ratio for source detection as well as range/depth localization.

4.4 Dissertations and Theses

Presented are bibliographical data and abstracts on research on the subject topics.

1. Brienzo, R. K. (1987). "Velocity and Attenuation Profiles in the Monterey Deep-Sea Fan," SIO Reference 87-28, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, CA. (Under W. S. Hodgkiss, MPL) Presently employed with Pennsylvania State University, ARL.

Data obtained during a refraction experiment is used to estimate velocity and attenuation profiles in an area of thick sediments (2.5 - 3 km) on the Monterey Deep-Sea Fan. A 20 element vertical hydrophone array was deployed at mid-depth in 2800 meters of water. Explosive sources, set for a depth of 1820 meters, were detonated at ranges between 3.5 km to 37 kilometers from the array. Estimates of velocity as a function of depth, and attenuation as a function of freqeuncy and depth are obtained from an analysis of the pressure time series generated by the explosive charges and received at the array.

To find the velocity profile, the sediment is modeled as horizontally layered, laterally homogeneous medium. A least squares solution is found for the velocity gradients in each layer of the model. Velocity as a function of depth is obtained by integrating these gradients. A second approach to inferring velocity structure utilizes linear programming. Errors in the data are easily incorporated into the problem using this formulation. The method takes upper and lower bounds on the input data and gives as a solution upper and lower bounds on the velocity profile. All velocity profiles that are consistent with the data lie within these bounds.

A method of spectral ratios is used to estimate attenuation in the sediment as a function of frequency and depth. The sediment is again modeled as a layered medium, with each layer having a separate attenuation coefficient. Solving for each of the coefficients gives attenuation as a function of depth.

2. Eslambolchi, Hossein (1984). "Beam Steering of Electrically Segmented Piezo-
   Ceramic Ultrasonic Transducers Using Normal Mode Coupling," SIO Reference 84-
   38, Marine Physical Laboratory, Scripps Institution of Oceanography, San Diego,
   CA. (Under V. C. Anderson, MPL). Presently employed with Bell Laboratories.

   It is well known that normal mode coupling in large diameter piezoelectric plates causes serious
   difficulties when attempting to operate over wide frequency bands. As a consequence transducers are
   commonly constructed as a mosaic of elemental resonators, each of which has a predominant single mode
   of mechanical oscillation at the frequency of interest. Such transducer arrays may be electrically steered
   to angles other than normal by applying different phases of driving voltages to different elements. A
   continuous plate can also be used to steer a radiated beam using normal mode coupling in a narrow band
   system. The technique is to adjust the frequency of the driving voltage to match the travelling wave
   velocity of the normal mode which possesses the desired spatial phase relationship across the fact of the
   plate. If the electrodes of a continuous piezoelectric plate are segmented so that regions of the plate can be
   driven with different phases, adjacent normal modes corresponding to a sine-cosine spatial phasing can be
   preferentially excited to generate a travelling wave. A true travelling wave will suppress the strong mirror
   lobe that would exist if a standing wave were excited. The velocity of the wave will be frequency
   dependent and the wave number can be controlled to generate a steered radiated beam.

   In this research the theory of normal mode steering will be developed, the dispersion curve will be derived
   so the travelling wave velocities can be evaluated, and the effect of the mirror lobe due to the reflection
   from the edge boundary will be analyzed. Finally, the theory will then be verified by measurements on an
   experimental normal mode transducer which will be compared with a companion staved or mechanically
   segmented transducer.

4.5 ARL:MPL Technical Reports

Presented are bibliographic data and abstracts of MPL Technical Reports. These reports
are quite useful in the conduct of the research. They also document workshops or
seminars funded under the ARL:MPL Workshops and Seminars project.

1. Bishop, C. B., and F. N. Spiess (1985). "Seamount Seminar: 10-11 January 1985
   (U),"[1] MPL Technical Memorandum 377, Marine Physical Laboratory of the
   Scripps Institution of Oceanography, San Diego, CA. MPL-S-9/85. [SECRET]

   (U) This conference of scientists, engineers and naval officers was conducted by the Marine Physical
   Laboratory of the Scripps Institution of Oceanography, UCSD in San Diego, California on 10-11 January
   1985 with the support of the Office of Naval Research .

   (U) The objectives of this conference were to exchange information on the current state of knowledge of
   seamounts and on available technologies applicable to their exploration and use; to consider aspects of
   potential importance to naval operations; and to identify research objectives leading to increased
   understanding of seamounts and their naval applications.

2. Brienzo, R. K. (1988). "Statistics of a Chi-Square Random Variable Obtained from
   Independent Gaussian Samples with a Non-Zero Mean and Arbitrary Variance,"
   MPL Technical Memorandum 405, Marine Physical Laboratory of the Scripps
   Institution of Oceanography, San Diego, CA. [MPL-U-40/88]

   The mean and variance of a chi-square random variable are generally given for the case in which the chi-
   square random variable is derived from a process having a zero mean and unit variance. In this report, the
   mean and variance of the random variable found by squaring and summing N samples of an independent
   Gaussian process with a non-zero mean and arbitrary variance is derived.

3. Fisher, F. H., and C. B. Bishop (1987). "Proceedings of a Workshop on Passive Acoustics (U),"[1] SIO Reference 87-9, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, CA. MPL-S-41/86. [SECRET]

   The two principal objectives of this workshop were: (U)

   1. (U) to review what is known about acoustic propagation and noise in the ocean in order to assess how best to meet Navy needs for future low frequency (50-400 Hz) passive acoustic systems.

   2. (U) To identify technical concepts in array technology which could support the development of future low frequency passive acoustic systems.

4. Fisher, F. H., and C. B. Bishop (1987). "Stable Research Platform Workshop," SIO Reference 87-29, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, CA. [MPL-U-56/87]

   A workshop on stable oceanographic research platforms was held at the Marine Physical Laboratory, 29-30 June 1987. Research needs of several scientific disciplines, including physical oceanography, air-sea interaction, biological oceanography (especially bio-optics), and acoustics were discussed in detail with respect to the advantage of various stable platforms.

   This workshop was stimulated by recent requests involving the use of FLIP in weather conditions beyond its original capabilities, with more equipment and people than it could hold, and by the naval architect's opinion that FLIP, after 25 years of service, may be approaching the need for some expensive structural rework. While the immediate purpose was to consider requirements for a new FLIP, the workshop adopted a much broader approach recognizing the unique advantages of different stable platforms for particular research needs.

5. Hodgkiss, W. S. (1985). "VLF Workshop: 24-25 January 1985 (Classified Presentations) (U),"[1] MPL Technical Memorandum 376, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, CA. [MPL-S-11/85] [SECRET]

   The focus of this classified workshop was on the frequency region 1-30 Hz. The program included presentations by the participants followed by a discussion covering areas of potential Navy interest and future research objectives. A summary of the classified presentations is contained in this report.

6. Hodgkiss, W. S. (1985). "VLF Workshop: 24-25 January 1985 (U)," MPL Technical Memorandum 376, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, CA. [MPL-U-11/85]

   The focus of this classified workshop was on the frequency region 1-30 Hz. The program included presentations by the participants followed by a discussion covering areas of potential Navy interest and future research objectives. A summary of the presentations and discussion is contained in this report.

5. ONR Site Visit

An ONR on-site review of the 6.1 ARL-Project work at the Marine Physical Laboratory
was held on 23 May 1984. Presentations on projects funded by the subject contract
were heard by an ONR-appointed review committee. The review committee consisted
of

Capt. Lorin W. Brown (ONR)
Mr. Glen Greenland (NADC)
Dr. Alan Gordon (NOSC)
Dr. Michael J. McKisic (ONR)
Dr. Robert F. Obrochta (ONR)
Dr. Robert D. Ryan (ONR)
Dr. Robert L. Sternberg (ONR)

These presentations were assembled in hard copy[10] and distributed to the participants.
Dr. Sternberg prepared a written critique from the committee's review and was given to
MPL for consideration. It was concluded that the MPL-Scripps' projects were
important contributions to the Navy program.

6. Summary and Conclusions

The ARL program at the Marine Physical Laboratory has provided a significant means
for pursuit of the research objectives contained in our Navy Mission Statement.

This program has provided leverage to hire young researchers in fields of oceanography
having Navy relevance, such as acoustic and upper ocean phenomenology.

The ARL program has also provided seed money for developing new instrumentation
for oceanographic research, and for high-risk/high-payoff research areas, several of
which have evolved into 6.1 and 6.2 funded projects.

Workshops and seminars made possible by this program have brought together
scientists, naval officers, and R&D managers to develope the foundations for new
research thrusts important to advanced Navy capabilities in ASW.

The leverage provided by the ARL program has significantly enhanced both the quality
of the research and the competence of the research staff at MPL>

References

1. ARL:MPL Proposal UCSD 1629, dated 19 December 1979, from Drs. F. N. Spiess (Director) and Victor C. Anderson (Deputy Director) to Dr. Robert L. Sternberg, ONR Code 1125OA, for the performance period 1 November 1979 - 31 October 1982.

2. ARL:MPL:SIO:UCSD Proposal UCSD 891450, dated 19 July 1989, from Drs. Kenneth M. Watson (Director) and Fred H. Fisher (Deputy Director) to Dr. Marshall Orr, ONR Code 1125OA, for the performance period 1 October 1989 - 30 September 1990.

3. Annual Report for the ONR 6.1 MPL:ARL Project, dated 27 April 1982, from Drs. F. N. Spiess (Director) and Victor C. Anderson (Deputy Director) to Mr. Robert Ryan, Code 1125OA, for the fiscal years1980-83. MPL-U-17/82.

4. Annual Report for the ONR 6.1 ARL:MPL Project, dated 19 April 1985, from Drs. K. M. Watson (Director) and Victor C. Anderson (Deputy Director) to Dr. Robert L. Sternberg, ONR Code 1125OA, for the fiscal year 1984. MPL-U-21/85.

5. Annual Report for the ONR 6.1 ARL:MPL Project, dated 16 May 1986, from Drs. K. M. Watson (Director) and Victor C. Anderson (Deputy Director) to Dr. Robert L. Sternberg, ONR Code 1125OA, for the fiscal year 1985. MPL-U-25/86.

6. Annual Report for the ONR 6.1 ARL:MPL Defense Science and Engineering Apprenticeship Program, dated 22 January 1982, from Drs. K. M. Watson (Director) and Victor C. Anderson (Deputy Director), to Mr. Robert D. Ryan. MPL-U-5/82

7. Letter for the ONR 6.1 ARL:MPL Defense Science and Engineering Apprenticeship Program, dated 11 January 1985, from P. Jordan, to Dr. Robert L. Sternberg, ONR Code 1125OA. MPL File: 85.11.

8. Jaffe, J. S. and P. M. Cassereau (1988). "Multibeam Imaging Using Spatially Variant Insonification", Journal of the Acoustical Society of America, Vol. 83(4).

9. Jaffe, J. S., P. M. Cassereau, and D. J. Glassbrenner (199). "Code Design and Performance Characterization for Code Multiplexed Imaging", IEEE Transactions of the Acoustics, Speech and Signal Processing.

10. ONR 6.1 Interdisciplinary Program Review at the Marine Physical Laboratory, ONR Contract N00014-80-C-0220, 23 May 1984, San Diego, CA [MPL-U-33/84].

ONR/MPL GENERAL DISTRIBUTION LIST

Chief of Naval Research
Department of the Navy
Arlington, Virginia 22217-5000
  Code 12, 122(2), 125
  1121, 112, 1122,
  1123, 1125, 1125 OA,
  1125 GG, 23

ONRDET
Stennis Space Center
Bay St. Louis, Mississippi 39529-5004
  Code 125

Commander
Naval Sea Systems Command
Washington, D. C. 20362
  Code 63DB, 933A

Commanding Officer
Naval Ocean Research and
  Development Activity
Stennis Space Center
Bay. St. Louis, Mississippi 39529-5004
  Code 100, 110, 300, 330,
  200, 220, 240, 250, 270,
  320, 360, 350

Commander
U.S. Naval Oceanographic Office
NSTL Station
Bay St. Louis, Mississippi 39522-5004
  Atten: Bill Jobst

Assistant Secretary of the Navy
(Research Engineering & Systems)
Department of the Navy
Washington, D. C. 20350

Defense Advanced Res. Proj. Agency
TTO - Tactical Technology Office
1400 Wilson Boulevard
Arlington, Virginia 22209-2308
  Atten: John N. Entzminger

National Oceanic & Atmospheric
  Administration
Ocean Engineering Office
6001 Executive Boulevard
Rockville, Maryland 20852

Commander
Space and Naval Warfare
  Systems Command
Washington, D. C. 20360-5100
  Code PMW-180T, PMW-180-5

Commander
Naval Ship Res. & Dev. Center
Bethesda, Maryland 20084

Executive Secretary
Naval Studies Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Director
Strategic Systems Proj. Ofc.
Department of the Navy
Washington, D. C. 20361
  Code NSP-20

Commander
Naval Ocean Systems Center
San Diego, California 92152
  Code 00, 01, 16, 94,
  54, 541, 605, 71, 72, 701

Commander
Submarine Development Group ONE
139 Sylvester Road
San Diego, California 92106

Commanding Officer
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, California 93043
  Code L40, L42

Commanding Officer
Naval Underwater Systems Center
Newport, Rhode Island 20844
  Atten: E.L. Sullivan

Officer in Charge
Naval Underwater Systems Center
New London Laboratory
New London, Connecticut 06320
  Code 900, 905, 910, 930, 960

Director of Research
U.S. Naval Research Laboratory
Washington, D. C. 20375
  Code 2620, 2627, 5000, 5100, 5800

Officer in Charge
Naval Surface Warfare Center
10901 New Hampshire Avenue
White Oak Laboratory Detachment
Silver Spring, Maryland 20903-5000
  Attn: E232 Tech Library

Commanding Officer
Naval Coastal Systems Laboratory
Panama City, Florida 32401

STOIAC
Battelle Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Commander
Naval Air Systems Command
Washington, D. C. 20361
  Code 370

Commanding Officer
U.S. Naval Air Development Center
Attention: Bruce Steinberg
Warminister, Pennsylvania 18974

Director
Defense Documentation Center
(TIMA), Cameron Station
5010 Duke Street
Alexandria, Virginia 22314

Institute for Defense Analyses
1801 North Beaugard Street
Arlington, Virginia 22311

Superintendent
U.S. Naval Postgraduate School
Monterey, California 93940

Chief Scientist
Navy Underwater Sound Reference Div.
U.S. Naval Research Laboratory
P.O. Box 8337
Orlando, Florida 32806

Supreme Allied Commander
U.S. Atlantic Fleet
ASW Research Center, APO
New York, New York 09019
  Via: ONR 100 M, CNO OP092D1,
  Secretariat of Military,
  Information Control, Committee

Director
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Director
Applied Physics Laboratory
Johns Hopkins University
Johns Hopkins Road
Laurel, Maryland 20810
  Atten: J. R. Austin

Director
College of Engineering
Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Florida 33431

Director
Marine Research Laboratories
c/o Marine Studies Center
University of Wisconsin
Madison, Wisconsin 53706

Director
Applied Research Laboratory
Pennsylvania State University
P.O. Box 30
State College, Pennsylvania 16802

Director
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, Washington 98195

Director
The Univ. of Texas at Austin
Applied Research Laboratory
P.O. Box 8029
Austin, Texas 78712

Director
Lamont-Doherty Geological Observatory
Torrey Cliff
Palisades, New York 10964

Director
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Director
Inst. of Ocean Science Engineering
Catholic University of America
Washington, D.C. 20017

National Science Foundation
Ocean Sciences Division
Washington, D. C. 20550

Office of Naval Research
Resident Representative
c/o Univ. of California, San Diego
Mail Code Q023
La Jolla, California 92093

University of California, San Diego
Marine Physical Laboratory
Branch Office
La Jolla, California 92093